RELATION OF THE PHYSICAL AND BIOLOGICAL TO THE SOCIAL SCIENCES IN AGRICULTURAL RESEARCH

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The purpose of this paper is to consider some of the very intimate relationships which are found to exist among all the sciences, whether pure or applied. Particular reference, however, is made to the sciences ordinarily represented in the research work of the United States Department of Agriculture and the State experiment stations. As a background to the central thought, attention is called to some important trends in agricultural research and the relationships which they bear to practical agricultural developments.

The blood-kinship of the sciences traces back to the scientific method, constant study of which is more than worth while. It is not only the basis of effective research on the part of the individual, but also the pattern for collective thought and concerted action in the solution of problems that are of both regional and national importance.

Greater progress has been made in the development of the physical and biological sciences and their application to the problems of production than in the social sciences and their application to the problems of distribution, marketing, and rural life. So great, in fact, have been the improvements in the processes of production that the supply of both raw materials and finished products is leading population a merry chase. Since the days of Malthus, world population has just about doubled, and standards of living, though still unsatisfactory, have been greatly improved. It is well to remember, however, that while

population and the supply of economic goods have increased by leaps and bounds, man's intellectual and social progress has come at a slower pace and with a heavier tread.

The founders of the United States Department of Agriculture and the State agricultural institutions early adopted research in the physical and biological sciences as the most effective means of assuring agricultural advancement. The reasons for such a beginning are obvious. Talent for researches in these fields was available, and the farmers were more conscious of their productive needs than of their more strictly economic and social ones. With the rise of tendencies towards the commercialization of agriculture, talent has arisen in the so-called social sciences, and certain of these - farm management, agricultural economics, and rural sociology - have been added to the research family. It is thought that these newer accessions will serve to strengthen and broaden the foundations laid by the founders of agricultural research.

Just how to blend these newer efforts with those of the older physical and biological sciences and how to put their findings to work on the farms, in the homes, and in the hearts of rural people, are among the most important tasks confronting those in authority. In endeavoring to answer these questions, one will find much aid and encouragement in the record of achievement made by the pioneers in the development and utilization of the older, more perfectly developed sciences.

It must be encouraging to the social scientists to observe that the physical and biological sciences were not perfected in a day; nor did they arise simultaneously. Instead, their evolvement was a slow, painstaking process. "Discovery and invention did not spring full grown from the brains of men. The labor of a host of men, great laboratories, long, patient,

scientific experiment built up the structure of knowledge, not stone by stone, but particle by particle," said President Hoover in his Dearborn address. The unfoldment of the sciences have followed a definite sequence, beginning with mathematics many centuries ago and coming on down to modern times through astronomy, physics, chemistry, geology, and biology to modern psychology which is still in the making. The older sciences did not arise independently of each other; instead, the younger grew out of the older. An interesting present-day writer says: "One cannot gain much fundamental knowledge about any science until those preceding it in the sequence have been mastered, for every science except the first is dependent upon those that go before."

The older the science, the more nearly perfect is its development and the greater the ease with which it is applied to material for study. Conversely, the younger and the less developed the science, the greater is its dependence upon its older relatives for guidance towards progressive development and practical application. Chemistry, for example, arose out of mathematics, astronomy, and physics; and it, in turn, paved the way for the more recent sciences of biology and psychology. In a similar manner, chemistry, geology, biology, and psychology are paving the way for the growing sciences of economics and sociology. Mayer aptly says, "that the social science studies, if they are to be worthy of the name of science, must build upon the natural sciences and particularly upon geology, biology, and psychology."

The physical scientists have the advantage in that they can test their conclusions by the experimental method; whereas, the economist and the sociologist must leave the testing of their results to the practical world. We have not arrived at that stage in human advancement wherein social

experiments can be conducted on a laboratory basis, under conditions of satisfactory control.

It is well to observe that in all researches, whether physical, biological, or social, the method employed is fundamentally the same. The human mind knows but two laws by which its judgments are formed - the Law of Identity and the Law of Causality. The first, the basis of deductive reasoning, says that what is true of the group is true of each of its members. The second, the basis of inductive reasoning, says that every phenomenon has its determining cause and that, in accordance with immutable law, the same causes must invariably produce the same effects. In the physical and biological sciences, the laws governing cause and consequence are nature's laws and, except as further discoveries bring refinements in their expression, are said to be immutable. In comparison, the laws of economics and sociology governing cause and consequence are either bio-psychological laws of human behavior - many of which have not been discovered - or man-made laws pertaining to human relations and human institutions, most of which are subject to argument, if not to modification or change.

In all constructive thought - whether we are conscious of it or not - the logical syllogism is the reasoning mill. The thinker takes some "undying" principle as a major premise and some fact from phenomena studied as a minor, dumps them into the hopper of his reasoning machine, turns on the power, and a conclusion pours out of the spout. This is but the deductive prototype of the modern inductive method. It is the simplest pattern of constructive reasoning. Research would be a delightful pursuit if it had no greater complexities to unravel. The soundness of conclusions depends, in part, upon the validity

of the premises; in part, upon the mechanical perfection of the reasoning machine; and, in part, upon the scientific vision of the individual in charge. Even then, errors are prone to creep in and hide themselves in every unguarded nook and corner. In the absence of fundamental data or of an ability to express them, one may reverse the reasoning mill, feed in his Wishes through the spout, and up in the hopper will be found the "imperishable principle" desired.

The modern scientific method consists of a logical combination of inductive, deductive, historical, mathematical, and intuitive reasoning. For exactness, the language by which one gives expression to his concepts of phenomena, hypotheses, principles, and laws must be clear and explicit. To comply with this requirement as closely as possible, one resorts to definitions and to mathematical symbols and formulae.

Statistical method is but a convenient tool for use in mathematical, analytical research. Its usefulness in the older sciences needs no comment here. In farm management, agricultural economics, and rural life studies it is equally indispensable. Its use has contributed immensely not only to scientific developments in general, but to the solution of practical farm problems. It should be added, however, that in agricultural research, statistics is a means to an end; not an end in itself. The big things are the problems themselves, the modes of procedure, and the minds behind them. Statistical method is good, and its service is good, if the sample used is representative. We need better samples in many branches of research, but this is especially true in the social studies.

From the natural sciences we learn something of the type of mind that is suited to scientific research. Some of its essentials are worthy of mention. It is a mind possessing an exceptional development of curiosity - not idle

curiosity but the discriminating kind which segregates non-essentials from important facts. It is an obervent mind, one which notes similarities and differences and repeats observations as many times as may be essential to accuracy of conclusion. It is an imaginative mind; it formulates hypotheses and then endeavors to test them by further observation and experiment. It is a constructive mind; it perceives relationships and weaves significant facts into orderly bodies of knowledge. It is a fearless mind, unafraid to break away from customary prejudices and unsystematic modes of thought. More briefly stated, the scientific mind is one capable of counting, measuring, weighing, and describing things; interpreting them, and verifying conclusions. Out of such minds have come not only the research spirit, the scientific method, and the sciences themselves, but also their practical application to the solution of important problems. Out of such minds will come whatever further progress we may hope to achieve in the rural social sciences.

It is not necessary for a science to be fully mature before it becomes highly useful. No one doubts the value of biology, yet it is by no means mature. Genetics, though husky, is still but a youth. Nevertheless, it has stimulated progress in plant and animal breeding, and in related fields. Plant physiology is not full grown, but no one would challenge its worth. Many of its phenomena are fully as difficult to describe and to measure as those of the social sciences.

Farm management is young, yet its problems lend themselves to scientific study. It deals with the economy of production, considered from the individual or local viewpoint. It involves the study of the organization of the resources of the farmer, in land and equipment; crops and livestock; labor and proprietor-

ship into appropriate enterprises and types of farming. Moreover, it seeks to discover those natural and economic causes - soil, topography, market demands, personal preferences - which determine the types of farming in given areas. It is basic to any local or regional program of production that may be required to support an effective system of marketing.

Agricultural economics deals with production from a national and world-wide viewpoint, and with exchange (marketing, credits, prices, finance), distribution (of the national dividend), and consumption. It is rather well-developed as a science, and its importance is broadly recognized but it is by no means mature. It has some well-established principles or laws, and, where these leave off, empirical rules of immediate value begin.

The economist knows that men want as much in money or goods for their efforts as they can get. Value, therefore, becomes heart and soul of the science. He has no Law of Value, but a very good law of Supply and Demand and a workable Theory of Value. With these at hand, he has made excellent headway in the inductive study of prices, markets, and marketing phenomena.

Thus far, the full capacity of economics to serve agriculture has not been utilized. The economist should go further into the study of consumption. By so doing, both marketing and production plans may be made more effective. In addition, a better knowledge of consumption will go far towards the establishment of a Law of Value, which is the main thing needed to make of economics a full-fledged science. Agricultural economics is vitally related to all researches pertaining to soils, crops, and livestock, on the one hand; and to home economics and rural sociology, on the other.

Home economics, like agriculture, is a field of study, not a science.

It draws upon any and all the sciences for its needs. It draws very heavily, for example, upon chemistry, nutrition, and the several branches of biology. It draws also upon economics and sociology. Its business is to build up a body of knowledge.

Sociology "deals with men and their relationships in all their real complexities" - economic, biological, religious, aesthetic, and so on. It "studies and formulates functional relations between various forms of social phenomena." Rural sociology undertakes "to describe the relatively constant and universal traits or relations of the rural social world as distinct from the non-rural or urban social universe." Sociology is the youngest and probably the least developed of the pure sciences. It has relatively few principles and laws which have met with general adoption. It has, however, many empirical facts of immediate value regardless of its lack of scientific development. The rural sociologist can employ the scientific method for intensive studies of rural traits and relations, and present the public with clear-cut pictures of his discoveries. This will tend to lead people more and more into habits of constructive reasoning when dealing with sociological problems and, in addition, will help to develop the science.

In the rush of things, there is some tendency on the part of those in authority to place farm management, marketing, and rural life studies in the hands of immature workers. Mature talent is scarce and, for this reason, a more conscious and determined effort should be made to develop it. Probably the greatest headway will be made by the development of young men just out of college. With the aid of the deans, many promising young men, specially trained in the social sciences, may be selected for minor research positions. They should be given

every opportunity to develop scientific spirit, initiative, and imagination. They should be encouraged to pursue graduate study without extended delays and to lay broad foundations in the fundamental sciences.

If, after reasonable trial, they are found wanting in adaptation to research, they should early be shifted to more appropriate fields. In fairness both to research and to the men themselves, some selective processes should be employed. The Department of Agriculture and the stations, through their studies in farm management, marketing, rural life, and related work are affording opportunities for experience and, through their graduate schools, unrivaled opportunities for further study. In a few years more, the pressure for talent should thus be relieved. If constructive thought, intensive preparation, and mature experience are essential to the success of researches in the older sciences, these same characteristics are all the more essential to the success of researches in farm management, agricultural economics, and rural sociology.

Let us digress for a moment to consider some of the more recent developments in American agriculture. Just what do they suggest as to the direction which further advancement in agricultural research may take? Cooperative marketing is being fostered as never before, and, as a result of considerable experience, it is making headway. A National Cooperative Council, with headquarters in Washington, has been formed by the commodity groups, its purpose being to look after their common interests. A Federal Farm Board has been formed and given broad powers by Congress. The immediate objective is to place marketing on a more businesslike basis, and, at the same time, to support it with a more consistent program of farm production. It is realized

that no system of marketing will bring the improvements desired if the supplies of farm products are not, by some practical means, more accurately adjusted and adapted to the requirements of consumption - not only with respect to quantities produced but also diversity and quality. The ultimate objective is to assure to producers their proportionate share in the national dividend and to promote rural standards of living to as high a plane as our national ideals.

To attain these ideals, a new type of agricultural information is needed. Fragmentary and inconclusive facts will not suffice. What are wanted are entire bodies of useful knowledge, better connected and more comprehensive and convincing than have been available heretofore. These new demands are adding much to the responsibilities of the research agencies and to the complexities of administration. To meet these issues squarely and to measure up fully to the occasion, will require a keen appreciation of both the method of science and of scientific relationship. The major problems confronting American agriculture must be more clearly visualized, and all the strength of modern science mustered for their solution. New scientific talent must be discovered and developed, and the more experienced deployed to strategic positions of creative leadership. Existing projects must be re-examined as to intensity, method and objective; ill-designed inquiries must be weeded out and replaced by more significant projects; and isolated projects must be woven into well-balanced programs of research.

It is being realized more and more that individual effort, however effective, is proving inadequate for present needs. Work must be coordinated and no sector left unguarded in the line of attack. The guiding thought should be to retain all the benefits of individual initiative and scientific freedom

and, at the same time, to take the fullest advantage of the greater effectiveness which team-work brings to the organization as a whole. Collective thought and concerted action on a more extensive nation-wide scale must supersede scattered efforts in the front-line offensive against major obstacles.

Wherever tried, community of effort is yielding such significant results that it cannot be ignored. The social science group is dealing with rather broad problems, neither so clear-cut nor delimited in scope as those ordinarily encountered in the physical and biological fields. To safeguard conclusions, therefore, projects in farm management, marketing, and rural life, may often be carried to advantage in association with appropriate subject-matter departments. The subject-matter specialist can often contribute important details to the projects of the social group. The agronomist, for example, should be the better authority on soils, variety of corn or other crops, cultural methods, and the like; the specialist in animal husbandry, on types of livestock, their feeding and care; whereas, the farm economist should be the better judge of the economic relationships of soils, crops, livestock, and market prices, and types of farming.

The farm economist, in turn has much to contribute to the experimental work of the subject-matter specialist, in the form of economic viewpoints and broad perspectives of the larger needs of agriculture. Yet, in the interest of efficiency, each type of specialist should work primarily in his own particular field. The agronomist should remain agronomist, and the farm economist should remain farm economist, except as training and experience suggest shifts in professional work. The essential feature of coordinated work is to assign each specialist the particular task for which he is best suited, everything considered.

Then, too, there are many local and even regional problems in which the initiative of the State station is not only proper but essential to success; and many problems of broader regional or national interest in which the best headway can be made in cooperation with appropriate divisions of the Federal department. In all these relationships, it should not be overlooked that, for cooperation to be effective, it must be both genuine and sincere. It should be entered into by all parties at the inception of the joint project, rather than after it is planned and well under way. It must be something more, therefore, than loosely drawn memoranda of agreement and professions of mutual goodwill. It should be a double team, capable of pulling more than twice the load that either party to the agreement can pull when pulling alone. The success of cooperation and coordination of research depends in large measure, of course, upon the interest and initiative, the encouragement and support, of responsible leaders.

Many examples might be cited of successful efforts in which the physical and biological researches are being effectively blended with the social - both within station organizations and between the stations and the Federal Department. Just a few such examples, however, will serve as illustrations. At one of the stations, the farm management specialist is working with the animal husbandman, the veterinarian, and the chemist in the joint study of related problems pertaining to range livestock production. In this program of effort, the station is cooperating with the Federal bureaus of Animal Industry and Agricultural Economics.

In another instance, the economist is collaborating with subject-matter specialists in the study of dairy, poultry, fruit, and vegetable marketing.

The horticulturist, for example, is breeding special strains of cucumbers and other vegetables to meet the needs of the packers and canners.

At another station, the rural sociologist is relating his projects to those of the home economist, on the one hand, and the farm management specialist, on the other.

In another case, the station agronomist and agricultural engineer are jointly studying cotton ginning problems in cooperation with the Federal divisions of Cotton Marketing and Agricultural Engineering.

Obviously, the cotton industry presents an excellent example of existing opportunities for State and Federal cooperation on national problems in which the physical and biological sciences may be logically blended with the social. In a comprehensive study of cotton marketing problems, it was found that they extended all the way from the first steps in the process of production to ultimate consumption. A study of the qualities of cotton produced on the farm and consumed by American mills showed that the marketing problem is greatly complicated by the low qualities of American cotton produced. Considering the needs of the industry as a whole, it was found that satisfactory progress could not be made unless a number of technical problems were studied coincident with marketing. Among those contributing to a better knowledge of cotton are the following specialists: marketing economists, cotton technologists, textile engineers, chemists, physicists, physiologists, cotton breeders, agronomists, and home economists - not working alone upon their favorite problems, but all working together in a well-balanced program of cotton research. In the program of effort thus far developed, the following agencies are cooperating; a number of bureaus of the departments of Agriculture and Commerce; State stations and

other agencies from North Carolina to California - not to mention the Cotton Textile Institute of New York, ginneries, and other private agencies. Again, it may be observed that such harmony of effort cannot be realized except by virtue of the vision and the constructive leadership of responsible officers.

Cotton has been grown on a commercial scale in this country for nearly 150 years. The Department of Agriculture and the Cotton-Belt stations have been studying cotton problems separately, so far as funds permitted, for many years. In this way they have, in fact, made important contributions to our knowledge of cotton. But with what practical results? The answer is great volumes of dissociated cotton facts but no accepted philosophy of cotton, and no broad national policy pertaining to cotton production, marketing, and distribution. After all our long and varied experiences with cotton, the Cotton-Belt is still a land of declining soil fertility; lowering yields; a high percentage of short, inferior staples; farmers' markets which have been improved but little since the early days - and all that these suggest.

The foregoing is suggestive of both the needs of American agriculture at the present time and the type of research organization which will supply them. The basic unit of such an organization is the creative mind of the individual worker - referred to by a very explicit writer as the "reasoning machine." The next larger unit is the departmental group, and the next is the composite reasoning machine - an agricultural experiment station or a Federal bureau. For the most effective functioning of such a machine, two distinct types of minds are essential. The one is the creative mind of the individual worker, and the other is the "engineering" mind of the responsible leader - the director or chief. The functions of the engineering mind are of no less importance than those of the

individual minds which constitute the reasoning machine. Its function is to discover or develop creative minds for researches in the physical, biological, and social sciences, and to blend them properly in the construction of the composite reasoning machine. Its further function is to inspect this composite reasoning machine at regular intervals and to keep it in a high state of repair and adjustment. Finally, it becomes the joint function of State and Federal leaders - through cooperation and the coordination of effort - to pool their resources for the construction of a giant reasoning machine; - one big enough to cope successfully with the obstacles confronting American agriculture; to see that this giant machine operates smoothly; and to keep it constantly trained upon major objectives of national importance.

Out of these larger efforts should arise a more consistent national agricultural policy; less wasteful and more remunerative programs of production; and rural standards of living more in harmony with our country's productive capacity.